Water Management in Coffee

- Water consumption
- Wet processing
- Wastewater sources
- Wastewater treatment
Water Management in Coffee

140 litres of water
Coffee Berry

1: centre cut
2: bean (endosperm)
3: silver skin (testa, epidermis)
4: parchment (hull, endocarp)
5: pectin layer
6: pulp (mesocarp)
7: outer skin (pericarp, exocarp)
Coffee Processing

- **Dry Process**
  - Cherries sorted and cleaned by winnowing or flotation
  - Cleaned cherries sun dried for 4 weeks
  - Machine-drying may be used to speed up the process after the coffee has been pre-dried in the sun for a few days
  - **Dry process used for**
    - 95% of the Arabica coffee produced in Brazil
    - Most of the coffees produced in Ethiopia, Haiti and Paraguay,
    - Some Arabicas produced in India and Ecuador
    - Most Robustas
Coffee Processing

- **Wet Process (mostly for Arabica)**
  - Cherries sorted by immersion in water (good ripe fruit sinks)
  - Skin and some pulp removed by pressing through a screen
  - Mucilage and pulp is removed by wet or dry fermentation
  - Fermentation breaks down cellulose 12-36 hours
  - Washing
  - Drying
Coffee Processing

- Semi-wet process
  - Cherries de-pulped to remove the pericarp
  - Mucilage removed mechanically in upflow
  - Used in Colombia and Mexico to reduce water consumption
  - Semi-washed processing requires less time than washed processing but quality is inferior
Coffee Processing

- **Becolsub**
  - Developed in Columbia taken from Beneficio ECOLogicos SUB-productos
  - Reduces water contamination by up to 90% compared to wet processing
  - Pulping without water
  - Mucilage removed mechanically using <1m$^3$ water per tonne coffee
  - Mucilage is a potential by-product.
Coffee Processing

- The amount of water used in processing depends on the process.
- Recycling of water in the de-pulping process can drastically reduce the amount needed.
- Without reuse, consumption can be up to 20 m³/tonne.
- With reuse and improved washing techniques, consumption of 1 to 6 m³/tonne is achievable.
## Coffee Processing

<table>
<thead>
<tr>
<th>Country</th>
<th>Process</th>
<th>Water use m$^3$/tonne cherry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>India</strong></td>
<td>Semi-washed, wet processing</td>
<td>3</td>
</tr>
<tr>
<td><strong>Kenya</strong></td>
<td>Fully washed, reuse of water</td>
<td>4-6</td>
</tr>
<tr>
<td><strong>Colombia</strong></td>
<td>Fully washed and environmental processing (BECOLSUB)</td>
<td>1-6</td>
</tr>
<tr>
<td><strong>Papua New Guinea</strong></td>
<td>Fully washed, recycling use of water</td>
<td>4-8</td>
</tr>
<tr>
<td><strong>Vietnam</strong></td>
<td>Semi wet and fully washed</td>
<td>4-15</td>
</tr>
<tr>
<td><strong>Vietnam</strong></td>
<td>Traditional, fully washed</td>
<td>20</td>
</tr>
<tr>
<td><strong>India</strong></td>
<td>Traditional, fully washed</td>
<td>14-17</td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td>Semi-washed, mechanical demucilage</td>
<td>4</td>
</tr>
<tr>
<td><strong>Mexico</strong></td>
<td>Semi-washed, mechanical demucilage</td>
<td>3.4</td>
</tr>
<tr>
<td><strong>Nicaragua</strong></td>
<td>Traditional, fully washed</td>
<td>16</td>
</tr>
<tr>
<td><strong>Nicaragua</strong></td>
<td>Fully washed, reuse of water</td>
<td>11</td>
</tr>
</tbody>
</table>
Two sources of wastewater

- Pulping (~55% of volume)
- Washing (~45% of volume)

Both wastewaters contain sugars which begin fermenting to ethanol and acetic acid causing reduction in pH from ~7 to ~3-4
Pulping Wastewater

- Raw wastewater high insoluble COD up to 50,000mg/l
- After screening COD 5,000 – 9,000
- TN 50 – 110mg/l
- TP 9 – 15mg/l
- Sugars, proteins, pectins, (polysaccharide carbohydrates), acids polyphenolics (tannins) and alkaloids (caffeine)
- Fermentation begins and pH falls depending on length of contact time (min 4.2)
Wastewater

- Fermentation/washing water
  - Washing of the fermented beans
  - Pectins, proteins and sugars.
  - Concentration falls as washing progresses
  - COD 7,000mg/l initial – 50mg/l final
  - TN 150mg/l initial – 40mg/l final
  - TP 16mg/l initial – 8mg/l final
  - pH 4 initial – 7 final
Wastewater treatment

- Coffee processing is a batch process so wastewater no constant
- Pectin precipitates at low pH
- For anaerobic treatment or constructed wetland pH 6.5 - 7.5
- pH correction by CaOH$_2$ solubilises pectins COD increases from an average of 3.7 g/l to an average of 12.7 g/l.
- Flavonoids from the skin of the cherries increase colour
- Polyphenolics and flavonoid compounds may be removed by aerobic fungi
Khe Sanh Vietnam

Wastewater Treatment Process:
- **Wastewater** enters the system.
- **ACID POND** with a 6h HRT, pH 3-4.
- LIME addition for pH adjustment to 6-7.
- **UASB** unit for biogas production.
- **SETTLEMENT** for settling.
- **WETLANDS** for further treatment.
- **HYACINTHS** for final purification.
- **Discharge** to the lake.

**Key Parameters**:
- **pH**:
  - ACID POND: 3.8
  - NEUT: 6.1
  - UASB: 6.2
  - SETTLING: 6.5
  - WETLAND: 6.5
  - HYACINTH: 7.0
  - DISCH: 7.0
- **BOD**:
  - ACID POND: 20,000
  - NEUT: 10,000
  - UASB: 1,000
  - SETTLING: 800
  - WETLAND: 400
  - HYACINTH: 200
  - DISCH: 200
Wastewater

- Acid fermentation
  - Floating mucilage scum
  - Setting of solids
- Neutralisation
  - Produces calcium acetate
- UASB generates biogas
- Anaerobic settlement
- Re-aeration
- Wetlands planted with reeds
- Water hyacinth pond
Instant Coffee

- **Roasting**
  - rotating cylinders at 165 °C for 8–15 minutes
  - fluidized bed for 1-4 minutes
- **Grinding** to 0.5–1.1mm
- **Extraction with water** in 5-10 percolation columns at 155 to 180 °C
- **Coffee solution** to about 15-30%
- **Drying**
  - Freeze drying
  - Spray drying
Instant Coffee

- **Spray drying**
  - 5–30 seconds 270°C
  - Moisture content in 75-85% out 3-3.5%

- **Freeze drying**
  - Rapid freezing
  - Drying under vacuum
  - Condensation of water vapour
Instant Coffee

CLEANING & BLENDING → ROASTING → GRINDING & EXTRACTION

HYDROLIZE → AROMA

CENTRIFUGATION → FREEZE CONCENTRATION

SPRAY DRYING → TO STORAGE

FREEZE DRYING → TO STORAGE

LIQUID FILLING → TO COLD STORAGE

UNESCO-IHE
Institute for Water Education

Whitewater Limited
Consulting Engineers & Scientists
Instant Coffee

- Wastewater
  - Batch processing
  - Extraction wastewater
    - coffee grounds COD 10,000mg/l
    - High colour
  - Cleaning in place water
    - Alkaline detergents COD 1,000mg/l
Instant Coffee

- Spent coffee grounds adsorb a range of heavy metals including:
  - Cadmium
  - Lead
  - Copper
  - Zinc

- Can be used for wastewater treatment